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HIGH RESOLUTION RADAR
PART I - PERISCOPE DETECTION IN SEA CLUTTER

[UNCLASSIFIED TITLE]

N. L. Davis

High Resolution Branch
Radar Division

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By direction

May 9, 1957

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NAVAL RESEARCH LABORATORY
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ABSTRACT
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Experiments have been conducted with an 8-millimicrosecond pulse length X-band radar operating against snorkel and periscope targets. Five submarines were used for the measurements. The radar cross section of periscope was found to be between 10 and 100 square feet with occasional values above and below these values. Sea clutter was reduced by the system sufficiently to enable periscope detection under high sea conditions.

PROBLEM STATUS

This is an interim report; work on this problem is continuing.

AUTHORIZATION

NRL Problem R02-12,
Project NR 412-003
BuShips Problem S-1593
BuAer Problem EL-43001

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HIGH RESOLUTION RADAR
PART I - PERISCOPE DETECTION IN SEA CLUTTER
[Unclassified Title]

INTRODUCTION

Experiments with an 8-millimicrosecond pulse length, X-band radar were conducted to determine the effectiveness of a short pulse radar in detecting a submarine snorkel or periscope in the presence of sea clutter and to obtain radar cross-section information on such targets and on sea return.

RADAR SITE

These experiments were carried out at the Georgia Institute of Technology Test Site on the east coast of Florida at Boca Raton during the period August to December 1955. Available at this site was a 100-foot steel tower equipped with elevators so that an adjustable antenna height of 30 to 115 feet above the water could be obtained. The tower was located approximately 50 yards from the edge of the ocean. Radar experiments using submarines could be conducted from this site since the submarine could safely run submerged at a range of 1.5 miles.

Five submarines, each available to the project for a four-hour period on an "in transit" basis, were used.

5 October	USS BALAO
7 October	USS PICUDA
22 November	USS TRUMPETFISH
29 November	USS GUAVINA
8 December	USS SEA DOG

RADAR EQUIPMENT

An experimental high resolution radar system was designed and constructed at NRL. A ferrite circulator was used to provide about 30-db isolation between the transmitter and receiver and an X-band traveling-wave tube was used as a preamplifier. In addition to providing preamplification, the traveling-wave tube also served as a limiter to the leakage transmitter power and eliminated the danger of mixer crystal burnout.

The characteristics of the high resolution radar system are as follows:

Frequency	9375 Mc
Power Output (peak)	15 kw
Pulse Length	0.008 μsec

Repetition Rate	1800 pps
Antenna	8-ft parabola
Preamplifier TWT	Huggins Model HA 4B
Noise Figure	25 db
First IF Amplifier TWT	Huggins HA 1B
Second IF Amplifier TWT	Huggins HA 2B
IF Bandpass	2500 to 2700 Mc
Video Bandpass	100 kc to 100 Mc
Presentation	Delayed A
Sweep Lengths	50, 100, 250 or 1000 yd

OCEANOGRAPHIC AND METEOROLOGICAL EQUIPMENT

Wave height was measured with a Beach Erosion Board ocean-type step-resistance wave gage. The steel piling on which the gage was mounted was located 400 yards from shore where the water depth was about 25 feet. A cable to the land from the piling furnished wave height information to a recorder and power for the wave gage and the necessary obstruction lights.

Wind speed and direction were recorded throughout the test interval by means of an AN/UMQ-5 system with the sensing unit located at the top of the tower.

CALIBRATION

A corner reflector was located on the beach to act as a reference whereby the variations in the radar system's performance could be observed. A check on the corner reflector's observations was obtained by comparing the corner echo with that from a sphere suspended from a helium balloon. In this manner a free space reference was made.

RESULTS

One of the primary objectives of these experiments was the detection of small targets under various sea conditions. As was readily observed using this radar, the amount of sea return from ranges of 3000 yards or more was extremely low even for the heaviest seas encountered (six to eight foot waves).

Both periscope and sea return data were recorded originally on film as an A scope deflection. For analysis, the average periscope signal amplitude was measured for each frame in a sample; sample lengths varied from one to seven minutes at five frames per second.

Due to the quantity of sea return data obtained, an automatic film reader was used to measure signal amplitude distribution. The reader gave an indication of the largest readable signal photographed in a given frame. Because single traces were not readable some lower value between average and time peak amplitude was read.

As was mentioned previously, obtaining sea return data at submarine range proved to be impossible. Consequently, it was necessary to make close-in measurements of the sea.

Values of radar area per unit area for sea return at close range (250 to 1000 yards) were measured without regard to angle of incidence, polarization, weather, etc. Using these values of unit radar area, a signal return from the sea at a range of 3250 yards was computed. It was assumed for these computations that the ocean surface was "area extensive."

Equivalent radar cross-section areas are shown in Table 1 to give a starting point for preliminary high resolution radar design.

Figure 1 shows the distribution of the radar return from the attack periscope exposed two feet, the distribution of the sea return echo, and a comparison of magnitudes of these two returns. The shaded area of the sea return (Fig. 1) includes computed values (range 3250 yards) for all of the sea return data analyzed for all conditions observed. The shaded area for the periscope curve indicates the spread of the data for five separate runs at different ranges normalized to a range of 3250 yards.

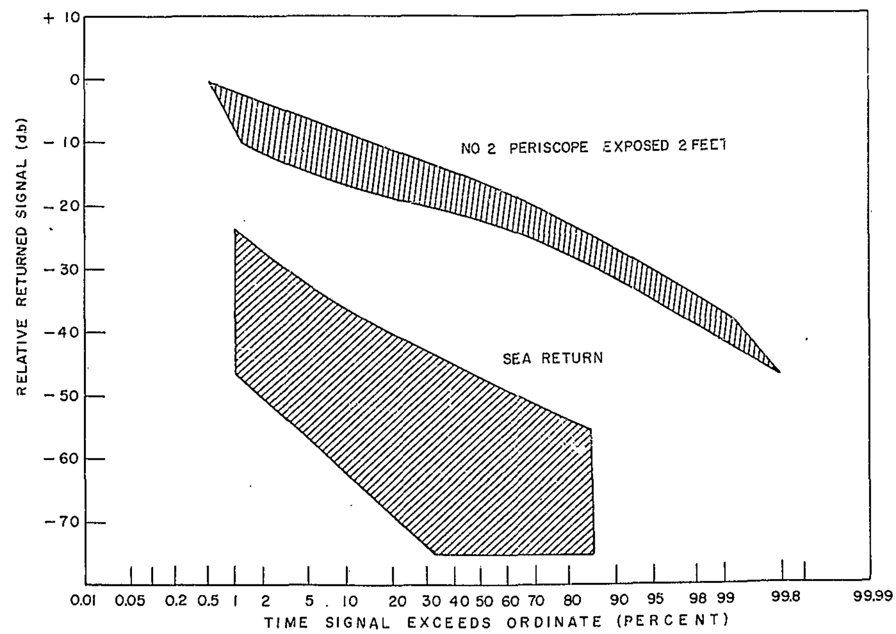

Fig. 1 - Amplitude distribution of radar return

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TABLE 1
Experimental Data

Date	Target	Range of Target (yd)	Wind		Wave Height (ft)	Radar Cross Section (ft)
			Speed (knots)	Direction (deg)		
	SS-382 Snorkle Depth	4850	17	110	5	1480
10/7/55	PICUDA 〃	6000	17	110	5	640
	〃	3100	17	110	5	170
	〃	3700	17	110	5	80
	〃	3100	17	110	5	720
	〃	3100	17	105	5	440
	〃	4100	17	105	5	400
	SS-425 No. 2 Per., 2 ft	6000	9	130	2.5	30
11/22/55	TRUMPETFISH No. 2 Per., 2 ft	3700	10	120	2.5	44
	No. 2 Per., 2 ft	3700	10	120	2.5	26
	No. 2 Per., 2 ft	3750	10	120	2.5	12
	No. 2 Per., 2 ft	3900	10	120	2.5	22
	No. 1 Per., 3 ft; Sn., 3 ft	4200	10	120	2.5	21
	No. 1 Per., 3 ft	5700	10	120	2.5	70
	Sn., 3 ft	5700	10	120	2.5	90
	No. 1 Per., 2 ft; Sn., 2 ft	7700	9	110	2.5	340
	No. 1 Per., 2 ft; Sn., 2 ft	7200	10	105	2.5	800
	SS-362 No. 2 Per., 2 ft	3250	12	350	2	44
11/29/55	GUAVINA No. 2 Per., 2 ft	4600	12	350	2	64
	No. 1 Per., 2 ft No. 2 Per., 2 ft	4500	12	230	2	56
	SS-401 No. 2 Per., 2 ft; Sn., 2 ft	3750	8	230	1	40
12/8/55	SEA DOG No. 2 Per., 2 ft; Sn., 2 ft	3850	8	230	1	212
	No. 2 Per., 2 ft; Sn., 2 ft	4000	8	230	1	540
	Sn., 2 ft	4300	8	230	1	48
	No. 2 Per., 2 ft	4300	8	230	1	34
	No. 2 Per., 2 ft; Sn., 2 ft	4050	8	230	1	720
	No. 2 Per., 2 ft; Sn., 2 ft	4900	8	230	1	160
	No. 2 Per., 2 ft; Sn., 2 ft	7300	8	230	1	220

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The 10 to 30 db separation between these shaded areas indicates that with the high resolution radar used in these experiments most of the sea return could be eliminated by amplitude selection alone.

Interpretation of the results of these experiments should be made with the following items taken into consideration:

1. The total number of runs per ship, which varied between three and eight, was small considering the many variables involved.

2. The dynamic range recorded by the radar was about 25 db, which prevented the gathering of data from sea return and periscope simultaneously due to their difference in amplitude.

3. The sea return echo using the short-pulse radar was too low to make significant sea return measurements at the minimum operating range of the submarine.

4. Since the submarines were available on an "in transit" basis, little control of the time of arrival could be exercised. Therefore, the weather at the time of arrival governed the conditions of the submarine tests.

CONCLUSION

On the basis of the text conditions described, it is concluded that a short-pulse radar will detect small attack periscope targets in various sea states by virtue of the large reduction in the amplitude of sea clutter that results from using a short pulse.

RECOMMENDATION

It is recommended that a shipborne installation of a high resolution radar having resolution characteristics similar to the one described in this report be made to conduct tests on the detection of small targets under a variety of open-sea conditions.

ACKNOWLEDGMENTS

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